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Pathways to Achieving Low Energy-Poverty Problems in Central African Nations with Government Effectiveness, Technology, Natural Resources and Sustainable Economic Growth

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Abstract: Central African nations, just like other African nations, have serious energy poverty problems, both in the rural and urban settings. With increased energy-accessibility problems, citizens have resorted to the use of conventional fuels, causing severe environmental degradation and affecting the health systems due to pollution. In this study, we address how energy poverty is alleviated with technology, natural resources and improved institutional quality. The interplay between these factors in improving energy accessibility is not widely understood; hence, key policies are lacking in the field. The data of Central African nations for the time period from 2004 to 2021 are utilized. The data are also analyzed with the 'Methods of Moments Quantile Regression' technique, ensuring the correction of 'cross-sectional dependence' and 'heterogeneity' that exists. The key findings depict that natural resource rent, government effectiveness and technology help in lowering energy poverty in Central African nations. Economic growth increases energy poverty, while green finance and foreign direct investment do not present a significant effect on energy poverty. Therefore, natural resources are a blessing in improving the accessibility of energy in this region, and this is also made possible with advancements in sustainable technology and proper institutional quality.

Keywords: technological innovation; energy poverty; green finance; income; institutional quality

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1. Introduction

The affordability and accessibility of energy in Central African Countries (CACs) is very low both in the rural and urban areas, leading to serious energy poverty problems in this region. Energy is fundamental in a country, and it is one of the key drivers of national income growth [1–3]. Thus, energy is considered as one of the key factors of production that is strongly linked with high growth rates in various economies. Therefore, it is fundamental for countries to ensure the accessibility and affordability of energy in order to improve people's standards of living. Casati et al. (2023) [4] Shows that the lighting in houses and on streets, and the powering of household appliances for cooking and machinery in industry require a reliable energy supply. Gonzalez (2023) [5] alludes to the fact that energy poverty implications are witnessed through the lack of safe, affordable and reliable energy. Thus, the access to polluting sources of energy, like firewood, charcoal and coal, in the rural parts of the African nations is a sign of energy poverty. Clean energy sources, like natural gas and electricity, are vital in promoting a clean environment and reducing the poverty rate through raising the income of the economy.

Figure 1 shows the access to electricity (AE, henceforth) of Central African nations (Angola (AGO), Burundi (BDI), Chad (TCD), Equatorial Guinea (GNQ), Gabon (GAB), Cameroon (CMR), Central Africa Republic (CAF), Congo Republic (COG), DR Congo (COD), Rwanda (RWA) and Sao Tome Principe (STP)) from 2004 to 2021, according to the data provided by [6]. Figure 1 shows that most of the Central African nations have a lack of electricity accessibility, except for Gabon and Sao Tome Principe, which have the highest level of electricity accessibility. Equatorial Guinea and Cameroon are better, as well, in regard to electricity accessibility, with a rate of above 50%. However, Figure 1 shows that most of the Central African nations are still wallowing in energy poverty crises, with energy accessibility being below 50%. For example, Burundi, Chad, Congo Republic and Rwanda have less than 20% energy accessibility.

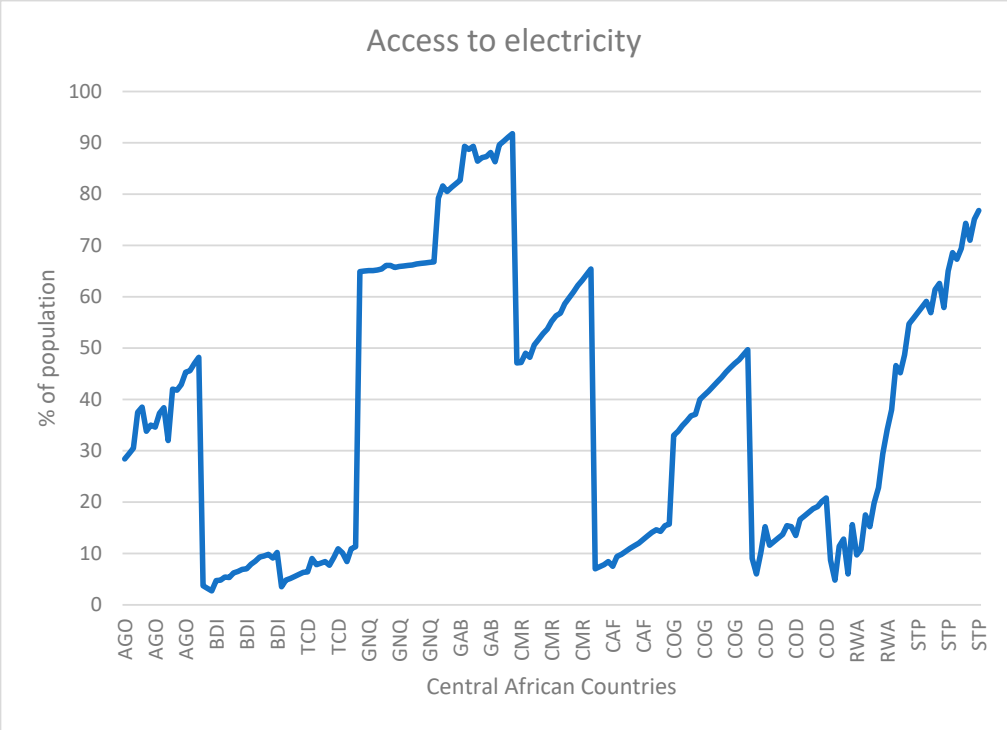

Figure 1. Access to electricity in Central African nations (data source: World Bank).

Figure 2 also shows the 'access to electricity and technologies for cooking in the urban areas' (ACU, henceforth) of Central African nations. Thus, Figure 2 helps to explain energy poverty in Central African nations from the side of affordability and accessibility of clean energy sources, which are vital in maintaining sustainability. Figure 2 shows that only Gabon and Angola have high levels of ACU as a percent of the total urban population. The other Central African nations are suffering in regard to access to clean energy for cooking in the urban areas; hence, this is a serious concern in these regions. Electricity affordability and accessibility are mostly required in urban areas where the population density per square meter is very high [7]. Thus, in such areas, cooking electricity should be provided to meet the needs of the households. However, despite the importance of energy accessibility in such areas, Central African nations are still struggling to meet and alleviate energy poverty in their countries. Central African nations harbor an abundance of natural resources (NRs), and if these NRs are efficiently exploited and used, it can mark the end of energy poverty problems in this region. Therefore, policies for improving energy accessibility and affordability in this region are needed. Such policies can only be presented through undertaking cutting-age studies addressing these problems and providing key implications.

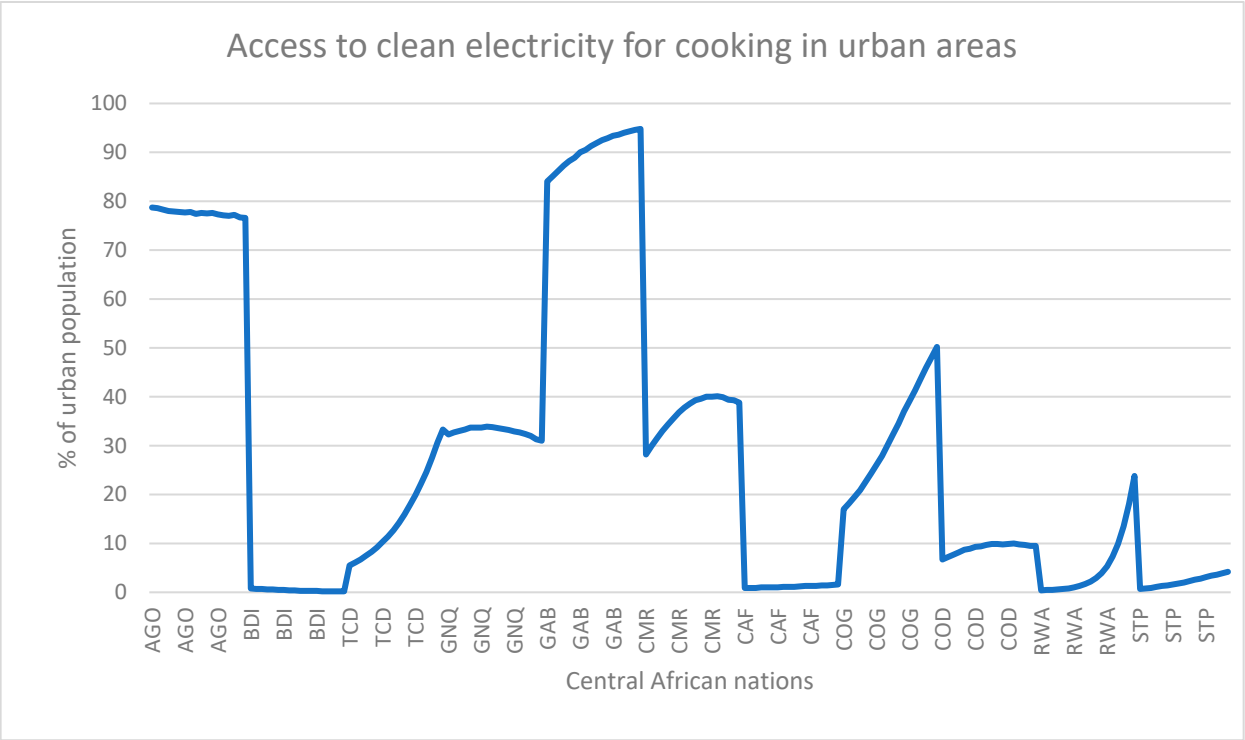

Figure 2. Access to clean electricity and technologies for cooking in the urban areas of Central African nations (data source: World Bank).

The current study seeks to address the problem of energy poverty in Central African nations, at a time when this region is wallowing in serious energy problems. Worse is the lack of studies addressing this problem and that are specific to Central African nations; hence, this research is a novelty in various ways. Firstly, it is one of the first studies addressing energy poverty in Central African nations in order to inform policies. It might be challenging to reduce energy poverty in the African nations when comparing them with developed nations because African nations lack technology and finance to support energy affordability. Usman et al. (2021) [8] highlights that renewable energy development is easily achieved in countries with high financial resources. The present study follows the energy-ladder and energy-stacking theories that differentiate between low-ladder energy sources like charcoal, which is used mostly in the rural areas, and the high-ladder sources like electricity, which is used in the urban areas [9]. The energy-stacking theory that arises from the existence of the multi-ladder phenomenon in which mixed energy ladder sources are used is also considered [10]. From these two theories, AE, as a percentage of the total population, and ACU, as a percentage of the total urban population, are used to develop the energy poverty index that is then subtracted from 100% to determine the energy poverty gap. Thus, by determining the energy poverty gap, the percentage of population lacking electricity access is determined and represents energy poverty in this region. Most past studies have just used energy accessibility, affordability and production indicators to represent energy poverty, and in [9], the concept of calculating the energy poverty gap is first adopted, to the best of our knowledge. Secondly, this research assesses the importance of technological innovation {TI}, economic growth, foreign direct investment (FDI), green finance (GF) and NRR in supporting energy accessibility in this region, hence, lowering energy poverty issues. Thirdly, this research also assesses the role of institutional quality, through employing government effectiveness, on energy poverty in Central African nations. This is crucial because most developing nations are associated with corruption, lack of rule of law and political instability problems, thus hindering economic

development in such regions [11]. Lastly, this research methodologically contributes to the literature through employing the 'Methods of Moments Quantile Regression' (MMQR) that overcomes 'heterogeneity' and 'cross-sectional dependence' (CD), as well as presenting heterogeneous findings in different quantiles [12].

2. Literature Gap and Contribution

Energy poverty in Central African nations has received limited attention in the existing literature, despite studies addressing energy poverty across Africa as a whole, albeit with some remaining gaps. Consequently, the available research on energy poverty in other African regions and globally can serve as a foundational background for this area. This body of knowledge can inspire advanced studies specific to Central Africa and inform the development of effective policy interventions.

The literature shows that energy poverty has long-term implications on various aspects of sustainability, such as the economic and social progress of a nation, 'environmental sustainability' (ES), and health systems, among many other aspects [13,14]. Therefore, Stewart et al. (2023) [15] recommend energy poverty issues to be addressed with techniques that are more comprehensive. Talking of the health outcomes, the use of polluting energy sources in cooking, that is, the traditional ways like the use of charcoal, firewood and coal, results in damage to the environment through pollution, leading to deteriorating health systems, as this will cause the outbreak of diseases. Dimnwobi et al. (2023) [16] have supported this notion by showing that relying on solid biomass energy in African countries pollutes and thus damages the surrounding environment. This is also supported in the empirical findings presented in the research of [17].

Most of the research performed to address energy poverty in African countries has focused on indicators that can be used as a proxy for energy poverty. For instance, Dimnwobi et al. (2023) [16] elaborated the need to advance accessibility of clean cooking energy in the cities of African nations. Ahmed et al. (2023) [18] concurs with [16] by showing that improvements in the accessibility of clean cooking energy in the cities of African nations is imminent. Urbanization is on the rise across the world, including in African nations, thus increasing energy demands in the cities. While urbanization is rising in Africa, informal settlements have also increased in the cities, thereby presenting unique energy poverty challenges in this region [19]. Such unique challenges brought about by the energy poverty that is widespread in African nations can be addressed by employing unique and special techniques. Therefore, such unique techniques need to be developed and used to eradicate this problem.

Tsai et al. (2023) [20] advocated for a comprehensive method to address energy poverty that encompasses community engagements, technological aspects, financial tools and policies. Poorly formulated policies for addressing energy poverty are found to hinder the production of renewable energy (RE) [21]. Therefore, this calls for Central African nations to come up with a policy framework that is conducive in attaining accessibility and affordability of energy for all. While it is important to devise a proper policy framework that enables the attainment of energy affordability and accessibility, Belaid et al. (2022) [22] postulate that in the European Union (EU), energy prices that are high, and the policies promoting a transition to green energy worsens energy poverty. Additionally, Song et al. (2023) [23], citing world reports, point to the emergency of inequalities in the income levels as a direct offshoot of energy scarcity. Thus, Belaid (2022) [22] articulates that new emerging inequalities can be prevented through properly formulating policies that are vigorous. Some poorly designed climate change policies may lead to new inequalities, as observed in some green transition policies in the EU, leading to energy poverty problems, and these need to be reformulated and redesigned. Belaid and Flambard (2023) [24] further

highlighted that skyrocketing energy prices among low-income earners using more energy cause their expenses to rise in Egypt.

This calls for such nations to ensure energy affordability through reducing energy prices or raising national income, which in turn raises disposable income for households. Belaid (2022) [25] also points to the need for educational advancements, economic stabilization and improvements in the income levels of the economy in addressing this problem. Increased income levels among households increase the affordability of energy and reduce energy poverty. Households' income is raised through human capital when the level of employment is raised. Thus, Quito et al. (2023) [26] and Van Der Kroon et al. (2013) [27] argue that human capital, leading to high income levels among people, further causes households to substitute conventional fuels with cleaner fuels, leading to increased ES. Zafar et al. (2019) [28] state that human capital ensures the use of technologies that are energy efficient, and the efficient exploitation of NRs is encouraged. With advanced technologies and the efficient harnessing of NRs, energy poverty is lowered. While human capital and technology can be seen as important tools to advance energy accessibility, Central African nations and many other African countries are still facing technological challenges, and the level of human capital is low too. This calls for key policies in advancing technology and human capital in addressing the problem of energy poverty.

The importance of income in improving energy accessibility and affordability through raising income levels, as explained above, is strongly connected to the postulations showing the importance of financial resources in lessening the problem of EP. Hassan et al. (2023) [29] show that richer households with more financial resources have the ability to access clean energy, and this is key in reducing EP while also protecting the environment. Hassan et al. (2023) [29] further emphasized the importance of subsidies from the government to households to ensure energy affordability to all. Energy subsidies for households do not only reduce EP but also improve the well-being of people. While government subsidies are important in improving well-being by reducing EP, they should be made on RE that also contributes to ES [30]. By subsidizing RE rather than fossil fuels, a transition to clean fuels can be achieved [31].

Evidence presented in the literature, as outlined in this section, shows the need for more work in addressing EP in Central African studies, as studies on this subject are scarce. In all African nations where limited research is present, more work is required in order to inform policies that support the accessibility and affordability of energy in this region. As noted in the work [30], empirical studies on EP poverty in the African nations are limited. Therefore, in the current research, we explore various mechanisms that can be employed to alleviate this problem in Central African nations. We explore the contributions of technology, GF, economic growth, FDI, government effectiveness and NRR to improving energy accessibility. With the existence of poor technologies in Central African countries, the findings of this research can persuade policies meant to foster advancement in technology to attain lower EP. Moreover, this research can inform policies that encourage the efficient exploitation of the abundant NRs in Central African nations and the use of the revenue generated thereof to advance the affordability of energy in this region. More policies for advancing the reduction of energy poverty can be devised by ensuring support for the advancements in national income, foreign investment and the efficient use of green finance to achieve an economy associated with low EP crises and clean environments that are not hazardous to health, through clean technologies and RE, thus improving social well-being. Moreover, the analysis presented in this research on how government effectiveness can be formulated in solving the energy poverty crises is crucial and helps Central African nations to promote improvements in the institutional quality of the nations by adopting vigorous policies.

3. Materials and Methods

3.1. Theoretical Background and Model Specification

The energy ladder and energy stacking are the key theories in understanding energy poverty in developing nations. The energy ladder theory categorizes energy sources into different ladders—low ladder and high ladder [9]. Low-ladder sources include wood, charcoal or coal, while high-ladder sources include electricity or natural gas. Thus, as nations develop, low-ladder sources are substituted for high-ladder sources [9]. Thus, in developing nations, low-ladder sources are used even if high-ladder sources are available and can be used together, resulting in what is termed the multi-ladder overlap phenomenon; hence, the energy stacking theory comes into play [32]. Thus, the conventional energy accessibility measurement is usually ineffective where the multi-ladder overlap phenomenon is present [10]. The energy ladder theory shows the importance of income through human capital in influencing energy poverty, as increases in the income level trigger households to consider substituting conventional energy sources with sustainable and modern sources [26,27]. Thus, a transition by households to cleaner energy sources is triggered by increases in the disposable income of households, and such increases are made possible through rising human capital levels. This is so because increases in human capital comes from an increase in educational opportunities, thus raising the employment levels and, hence, the income of households, resulting in improvements in the affordability and accessibility of energy for households. Human capital is also fundamental for many different facets. With skilled and educated people, technologies that are energy efficient can be utilized; hence, efficiently exploiting the NRs and reducing energy poverty can be achieved [28].

From the energy ladder and stacking theories, it is inevitable that income/finance and technology are key in promoting the accessibility and affordability of energy. Therefore, in formulating the research model of this study, economic growth, the national income; FDI, the income generated from foreign investment; and NRR, the revenue from the sale of a country's NRs, are specified as the independent variables. Moreover, technological innovations and green finance, which is used to advance R&D in clean fuels and clean energies, are specified as the independent variables too. The model specifications are shown in Equation (1).

$$EP_{i,t} = \delta_0 + \delta_1 EG_{i,t} + \delta_2 GF_{i,t} + \delta_3 TI_{i,t} + \delta_4 FDI_{i,t} + \delta_5 NRR_{i,t} + \delta_6 GE_{i,t} + \mu_{it} \quad (1)$$

Here, we show that the dependent variable is energy poverty (EP). Independent variables are economic growth (EG), green finance (GF), technological innovation (TI), foreign direct investment (FDI) and natural resource rent (NRR). Government effectiveness (GE) is the control variable, representing the institutional quality that is important in the attainment of energy poverty. We also show that ***i*** and ***t*** superscripts stand for the cross-sections and time for the panel data used. The model parameters are represented by the coefficients, δ_1 to δ_6; and the y-intercept, δ_0.

3.2. Data

In this research, annual data of the eleven Central African nations are used. The period for the data considered is from 2004 to 2021. The data were retrieved from the World Bank (WB), except for the data of green finance, as they were collected from Our World in Data (OWID). In determining the energy poverty in Central African nations, an energy poverty gap (EPG) is calculated in two stages. Firstly, the data of access to electricity (AE) and ACU are used to calculate the energy poverty index (EPI) with the method of geometric mean. Both AE and ACU are measured as a percentage of the total population in a nation. Second, the energy poverty index calculated is subtracted from

100% to determine the energy poverty gap ($EPG = 100 - EPI$). The energy poverty gap, when calculated in this way, shows the percentage of the population that has no access to electricity; hence, it serves as the most appropriate representation of energy problems in Central African nations. Moreover, this research develops the aggregated index of technological innovations from Fixed Broadband Subscriptions (FBS), Internet usage (IU) and Mobile Cellular Subscriptions (MCS) dimensions, where FBS and MCS are measured in per hundred persons and IU is measured as a percent of the total population. Principal Component Analysis (PCA) is used to develop this aggregated index. The NRR is the revenue generated by a nation from selling its natural resources, like oil. Government effectiveness is a rank between −2.5 and 2.5, measuring the institutional quality in a nation. FDI is the inflows of foreign investment measured as ratio of GDP in percent. Economic growth is the rate of national income growth in percent. Green finance is measured as the total amount, in dollars, received by developing nations to support R&D in RE and clean technologies. The sources of the variables and the measurements are summarized in Table 1, while their descriptive statistics are given in Table 2.

Table 1. Summary of variables measurements and source.

Variable	*Source*	*Measurement*
Energy Poverty Gap (EPG)	WB	100%—EPI
Green Finance (GF)	OWID	Total amount in dollars
Economic Growth (EG)	WB	National income growth in %
Natural Resources Rents (NRR)	WB	Total revenue generated from the sale of NRs as ratio of GDP in %
Technological Innovations (TI)	WB	Aggregated index of IU, FBS and MCS
Government Effectiveness (GE)	WB	Rank between −2.5 and 2.5
Foreign Direct Investment (FDI)	WB	FDI inflows as % of GDP

Table 2. Descriptive statistics.

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
EPG	198	70.8324	26.5743	6.7120	98.6509
EG	198	3.8481	6.4752	−36.3919	37.9987
FDI	198	4.2512	7.3788	−18.9177	42.0928
NRR	198	20.6509	13.9637	1.8843	56.2891
GF	198	3.3300000	1.37000000	0	1.280000000
GE	198	−1.0998	0.4331	−1.8794	0.2740
FBS	198	0.2044	0.4411	0	2.7276
IU	198	12.3523	14.9749	0.1962	71.7494
MCS	198	47.3399	34.6431	1.2794	149.1076

3.3. Method

The MMQR method is employed in this research in analyzing the relationship that is specified in the model proposed in Equation (1) [12]. The use of the MMQR method is determined after running various tests on the variables, as well as on the model, which points to the use of the MMQR method as the most appropriate one. The test of CD on each variable (Pesaran, 2004) [33] enables us to use the CIPS technique to investigate the unit root (UR) in each variable (Im et al., 2003) [34]. Moreover, the Frees (1995; 2004) [35,36] method, along with the Pesaran (2015) [37] and Friedman (1937) [38] methods, is used in checking CD in the model. Thus, the presence of CD in the model, according to these tests, points to the selection and use of 'second-generation' (SG) methods like the MMQR technique in the analysis of the relationship presented in the model. This is because the MMQR method overcomes this problem. The 'heterogeneity' problem that exists, according

to the test carried out with the 'slope heterogeneity' test, also ensures the selection and use of the MMQR method (Pesaran & Yamagata, 2008) [39]. Thus, the MMQR method is useful in overcoming this problem and presents robust outcomes. Moreover, the cointegration in the model according to the Kao and Pedroni techniques (run by selecting the option of subtracting 'cross-sectional means', a process called demean in order to overcome CD) promotes the use of the MMQR technique, which presents heterogeneous outcomes in different quantiles where the upper quantiles give the long-run (LR) outcome and the lower quantiles give the short-run (SR) outcomes. Therefore, the MMQR statistical equation is specified in Equation (2).

$$Q_y(\delta!X'it) = \delta_0 + \delta_1 EG_{i,t} + \delta_2 GF_{i,t} + \delta_3 TI_{i,t} + \delta_4 FDI_{i,t} + \delta_5 NRR_{i,t} + \delta_6 GE_{i,t} + \mu_{it} \quad (2)$$

In Equation (2), the conditional quantile-dependent variable of the energy poverty gap is represented by the term $Q_y(\delta!X'it)$, and the other parameters and variables specified in the model are explained in Equation (1).

A robustness test was performed with the Panel-Correlated Standard Errors (PCSEs) method (Beck & Katz, 1995) [40].

4. Results

4.1. Pretesting Findings

Table 3 presents the outcomes of CD for every indicator that is specified in the model. This is performed to enable the identification of the technique to be used in investigating UR in the indicators. Table 3 shows that EPG, EG, NRR, GF and TI have significant (sig.) CD, while FDI and government effectiveness have no CD. The existence of CD in the majority of the indicators specified in this study leads to the utilization of the SG methods that present reliable outcomes when CD is present in the indicators.

Table 3. Results of CD test.

	Statistic	***p-Value***
EPG	14.81 ***	0.000
EG	7.76 ***	0.000
FDI	−0.87	0.383
NRR	12.88 ***	0.000
lnGF	3.39 ***	0.001
TI	29.16 ***	0.000
GE	0.36	0.721

Note: *** sig. at 1%.

Table 4 presents the CIPS findings of UR for the indicators specified in this research. The outcomes presented in Table 4 depict that EPG, NRR and TI are I(1), while EG, FDI, government effectiveness and GF are I(0). Therefore, the UR results presented point to the existence of mixed integration orders in the indicators employed in this study. Therefore, employing methods that work with such indicators is vital for the presentation of reliable findings.

Moreover, Table 5 shows that the independent indicators specified in the model of the study have no issues of 'multi-collinearity'. This is shown by the VIF value for each independent variable that is less than 10. This ascertains that the independent factors that are specified in the model are not strongly related and hence can be specified as the independent factors in the same model.

Table 4. CIPS results of UR.

	Level	*1stD*
EPG	−1.429	−3.587 ***
EG	−3.603 ***	
FDI	−2.873 ***	
NRR	−2.004	−3.160 ***
lnGF	−4.095 ***	
TI	−0.812	−2.532 ***
GE	−2.526 ***	

Note: *** sig. at 1%.

Table 5. VIF results of multi-collinearity.

Variable	*VIF*	*1/VIF*
NRR	1.34	0.7441
GE	1.32	0.7590
TI	1.23	0.8114
LGF	1.17	0.8581
EG	1.16	0.8647
FDI	1.05	0.9545
Mean VIF	1.21	

Table 6 presents the cointegration outcomes of the specified model by utilizing two methods, that is, the Kao and the Pedroni tests. The Pedroni and Kao test results support the presence of cointegration in the model. This implies that the specified model has a strong LR connection, informing the need to employ methods of analysis that present the LR findings.

Table 6. Results of cointegration.

	Statistic	*p-Value*
Kao		
MDF	0.8990	0.1843
DF	1.2943 *	0.0978
ADF	3.0693 ***	0.0011
UMDF	0.1639	0.4349
UDF	0.6388	0.2615
Pedroni		
MPP	4.9626 ***	0.0000
PP	0.4941	0.3106
ADF	1.2313	0.1091

Note: *** sig. at 1%; * sig. at 10%. Subtraction of cross-sectional means is included.

Table 7 presents the findings of 'heterogeneity' and shows that this problem is exhibited in the model. The sig. of the delta statistics, together with that of the delta-adjusted statistics, shows that the specified model suffers from 'heterogeneity' issues. To correct for 'heterogeneity' issues and present reliable results, it is necessary to use the SG techniques.

Table 7. Results of 'heterogeneity'.

	Statistic	*p-Value*
Δ	4.773 ***	0.000
Δ-adjusted	6.404 ***	0.000

Note: *** sig. at 1%.

Table 8 also presents the 'weak CD' findings; the 'weak CD' is an important test in which panel data are used in the analysis. This test is essential because longitudinal data exhibit CD problems, which can only be corrected by utilizing SG techniques in the analysis. The results of the three tests used in Table 8 support the existence of 'weak CD' in the model.

Table 8. Results of 'weak CD'.

Test Method	*Statistic*	*p-Value*
Frees	1.364	
Friedman	21.003 **	0.0211
Pesaran	1.086	0.2773

Note: ** sig. at 5%.

4.2. MMQR Results and Discussion

The analysis of the specified model in this study is performed with the use of the MMQR method. The choice of method is based on the pretesting results that are presented in the section above. For example, the existence of 'heterogeneity' and 'weak CD' in the specified model informs the importance of using SG methods like the MMQR method that give reliable results because they are capable of overcoming these issues. Moreover, the MMQR gives LR outcomes in the upper quantiles; hence, the cointegration results that have shown the existence of an LR relationship are followed. This method also gives 'heterogeneity' results, a condition that is necessary to investigate asymmetric effects in the model. The PCSE method is also employed for the robustness test. The findings of the MMQR and PCSE methods are given in Table 9 and explained below.

Table 9. Results of MMQR and PCSE techniques.

	Coefficient	*z-Statistic*	*p-Value*	*Coefficient*	*z-Statistic*	*p-Value*
			MMQR Results			
		0.1 Quantile			**0.75 Quantile**	
EG	1.0598 ***	0.3660	0.004	0.2505	0.2236	0.263
FDI	0.3884	0.2804	0.166	0.1249	0.1726	0.469
NRR	−1.4571 ***	0.1756	0.000	−1.0152 ***	0.1071	0.000
lnGF	0.1808	0.2791	0.517	−0.0026	0.1720	0.988
TI	−13.9108 ***	2.36434	0.000	−15.7851 ***	1.4560	0.000
GE	−39.3769 ***	6.9365	0.000	−5.7704	4.0735	0.157
		0.25 Quantile			**0.9 Quantile**	
EG	0.7366***	0.2678	0.006	0.0603	0.2640	0.819
FDI	0.2832	0.2025	0.162	0.0630	0.2021	0.755
NRR	−1.2806 ***	0.1290	0.000	−0.9113 ***	0.1267	0.000
lnGF	0.1075	0.2010	0.592	−0.0457	0.2011	0.820
TI	−14.6592 ***	1.7060	0.000	−16.2256 ***	1.7041	0.000
GE	−25.9573 ***	5.4097	0.000	2.1284	5.0229	0.672
		0.5 Quantile			**PCSE Results**	
EG	0.4682 **	0.2188	0.032	0.5053 ***	0.1807	0.005
FDI	0.1958	0.1671	0.241	0.2079	0.1406	0.139
NRR	−1.1341 ***	0.1051	0.000	−1.1543 ***	0.0804	0.000
lnGF	0.0467	0.1662	0.779	0.0551	0.1484	0.710
TI	−15.2809 ***	1.4086	0.000	−15.1950 ***	2.4718	0.000
GE	−14.8108 ***	4.2205	0.000	−16.3505 ***	2.3391	0.000

*** sig. at 1%, ** sig. at 5%.

Firstly, the results in Table 9 depict that NRR is important in alleviating EP in Central African countries. The importance of NRR in reducing EP is observed to be sig. in all the quantiles; hence, the existence of symmetric effects of NRR lowers EP in this region. Table 9

shows that an increase in the NRR in the 0.1 to the 0.9 quantiles causes EP to decrease by an average magnitude of 1.457 units to 0.91 units, respectively. The effect of NRR in ensuring EP is reduced in this region is very strong because of the results that are sig. at the level of 1% and a high coefficient value presented in all quantiles. The PCSE method also supports the importance of NRR in reducing EP in Central African countries. The results of the PCSE method employed show that a 1-unit rise in NRR reduces energy poverty by an average of 1.154 units. Therefore, it is important for Central African countries to capitalize on NRR to ensure advancements in the production and consumption of energy, reducing the problem of EP in this region. The importance of NRR in advancing accessibility of energy sources, as shown by the results in Table 9, supports the resource bless (RB) hypothesis, which articulates that countries with an abundance of NRs can advance their economies through harnessing and using these resources (Rostow, 1961) [41]. The recent empirical research of Deka and Efe-Onakpojeruo (2024) [30] supports that NRR supports the accessibility of energy for cooking in the African nations. This is contrary to the RC theory, which articulates that developing nations, though they might have abundant NRs, may fail to benefit from these NRs due to instability in the political system and the levels of corruption that might be high (Auty, 1994) [42]. Other empirical studies have also shown that NRs are not supporting development in the developing nations (Sha, 2023; Khan et al., 2023) [43,44]. However, in Central African nations, the revenue generated from NRs can be utilized to ensure that EP is lowered and energy accessibility is improved.

Moreover, it is shown that TI plays a crucial role in reducing EP in Central African countries. The MMQR results show that TI symmetrically affects EP in Central African countries through reducing EP in all the quantiles. A rise in TI by 1 unit in the 0.1 to 0.9 quantile is associated with a decrease in the EP gap in a range from 13.91 units to 16.23 units. The results of the PCSE method also support this observation by indicating that a 1-unit rise in TI increases EP by approximately 15.19 units. The effect is also significant at the level of 1%, and the coefficient values are very high, depicting the strong influence of TI in eradicating EP in this region. Technological advancement is important in inventing new and clean sources of energy that are cheap; hence, it has the capacity to ensure that EP is eradicated. Quito et al. (2023) [26] and Van Der Kroon et al. (2013) [27] have shown that technologies that are supported with improved human capital support energy affordability and accessibility. With sophisticated technologies, efficient energy production and the harnessing of NRs are facilitated. This is supported by the postulations of the energy ladder theory. Therefore, it is important for Central African countries to consider advancements in technology to ensure a reduction in energy poverty in this region.

In addition, Table 9 shows that government effectiveness is key in reducing EP in Central African countries. The outcomes of the MMQR technique depict that increasing government effectiveness by 1 unit in the 0.1 to the 0.5 quantiles reduces EP by 39.38 units to 14.81 units on average. The effects of government effectiveness in lowering EP in Central African countries is observed to be asymmetric, as this is sig. in the lower and middle quantiles but becomes insig. in the higher quantiles. Therefore, Central African countries with low-EP problems tend to benefit from government effectiveness in ensuring the increase in the production and consumption of energy in their countries. However, countries with serious EP, as depicted by the 0.75 and 0.9 quantiles, do not significantly benefit from government effectiveness in promoting energy utilization and production. These findings can also show that government effectiveness lowers EP in the SR but fails to significantly eradicate EP in the LR. The outcomes of the PCSE technique are also in support of the importance of government effectiveness in lowering EP by showing that a 1-unit increase in government effectiveness leads to a 16.35-unit decrease in EP. The importance of government effectiveness and governance in improving energy accessibility and

affordability in Central African nations is supported by the empirical outcomes presented in the research of Deka and Efe-Onakpojeruo (2024) [30] and Aluko et al. (2023) [45]. Deka and Efe-Onakpojeruo (2024) [30] show that government effectiveness improves energy accessibility for cooking in the SSA nations. Therefore, it is important for Central African countries to improve government effectiveness and, hence, reduce EP in their regions.

While the above-mentioned factors reduce EP in Central African countries, Table 9 demonstrates that GF does not significantly affect EP in this region, though the coefficient value is positive in the lower quantiles and negative in the upper quantiles. GF is expected to alleviate EP since these funds are meant to support the development of clean energy sources (Our World in Data, 2024) [46]. Thus, as clean energy sources are enhanced, accessibility of energy in these developing countries should also be enhanced. Therefore, the insignificant effect of GF in promoting energy production and accessibility, as observed in this study, is best explained by the existence of corruption in the developing countries where funds meant to support the development of clean energies can be embezzled and used for other purposes (Auty, 1994; Deka & Efe-Onakpojeruo, 2024) [30,42]. Thus, this study suggests that developing countries help to ensure that the funds meant for the development of clean energies are used for the intended purpose and, hence, EP can be alleviated.

Moreover, Table 9 shows that FDI does not significantly affect EP. However, MMQR results are positive in all quantiles, and this outcome is supported by the PCSE results too. Thus, while FDI's impact is insig., the positive outcome informs policy makers that FDI might be detrimental to EP. Deka and Efe-Onakpojeruo (2024) [30] support this notion by showing that FDI worsens EP in the African nations. However, Magnani and Vaona (2016) [47], and Sarkodie and Adams (2020) [48] have shown that FDI may be beneficial in ensuring energy accessibility and affordability. Therefore, it is important for Central African countries to put into place some policies that regulate FDI and national income in order to capitalize on these funds and move toward elevating energy poverty.

Table 9 shows that economic growth worsens EP in Central African countries. However, economic growth is observed to present significant asymmetric effects on EP, whereby the lower-quantile results are sig., while the upper-quantiles are insig. MMQR outcomes show that an increase in the economic growth by 1 unit results in an increase in EP in the 0.1 and 0.5 quantiles by average of 1.06 and 0.47 units, respectively. The PCSE method also supports this observation by showing that a 1-unit increase in economic growth is associated with a 0.505-unit increase in EP. The detrimental effects of economic growth on EP in Central African nations is not supported by the findings of Bai and Liu (2023) [49], as they have shown that economic growth is associated with a reduction in the EP. Van Der Kroon et al. (2013) [26]) and Quito et al. (2023) [27] have also supported the importance of income in ensuring the accessibility of affordability of energy, as supported in the energy ladder theory. Kareem et al. (2023) [50] has also shown that economic growth is fundamental in raising the utilization of energy in South Africa. Thus, with increased energy use because of increases in the national income, EP will be lowered.

5. Conclusions

In conclusion, this research gives two insights into how EP can be eradicated in Central African countries, as well as in other African countries that have similar characteristics in terms of the income, technology, EP level, and resource level. Most African countries are struggling with the accessibility of energy yet have an abundance of NRs that can be harnessed in order to solve this problem. Therefore, it is important to come up with cutting-edge studies that provide recommendations that are essential in formulating policies toward reducing EP in these countries. This also calls for the adoption of sustainability

measures in the utilization of energy sources, ensuring efficient use and conservation of energy sources for future generations. The major lessons presented in this study can be summarized according to five themes. Firstly, NRR in Central African nations where there is an abundance of NRs can be key in alleviating EP. This key theme is of great importance to most African countries that have an abundance of NRs and can inform policy implications in ensuring the revenue generated from NRs is used to maintain energy production and accessibility. Secondly, the present research informs policies toward the reduction of EP by supporting the importance of TI for this purpose. Thus, Central African nations need to advance technologies that support energy generation; hence, the accessibility of energy is enhanced in this region. Thirdly, the effectiveness of the government can be used to advance energy accessibility in Central African nations. By making policies and setting goals that advance energy accessibility in the country, the government can work toward a low-EP society. Fourthly, corruption and political instability in these developing countries is a major cause of concern, as they result in detrimental effects of GF on EP. With zero corruption and political-instability problems, the developing countries can be able to use the international finance meant to develop clean energy to improve energy accessibility in their regions and hence lower the EP problems. Fifthly, policy frameworks that are vigorous in their approach to ensuring that EP is corrected with economic growth and FDI revenues in the country should be adopted.

While this research uses the EP gap that has been developed from the energy accessibility indicators and not energy production indicators, the findings can be used to understand how EP can be eradicated, first in Central African countries and second in all African countries because of their similar income and technology levels and resource availability. The findings presented in the research are fundamental in informing policies on how these factors can be used to advance energy accessibility and production, as well as which factors need to be monitored to ensure that EP is eradicated for all. Thus, this study contributes to the body of knowledge by showing how developing countries with abundant NRs can use the revenue from these resources to ensure that energy accessibility is advanced. With the presence of theories such as the RC theory that have shown the insig. or negative effect of NRs on economic development in the developing countries, this study insists that developing countries can still benefit from NRs to advance and reduce EP in their countries. While this study has provided some key implications on the road to a lower EP, it is important to ascertain why developing countries such as these Central African countries may not benefit from GF in advancing and reducing EP. Thus, factors such as corruption and political stability should be explored more; hence, key implications are informed. Therefore, future studies can work on exploring the various methods that can be employed to lower corruption and political instability and, hence, improve the economic performance of developing countries.

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